THE USED TIRE TRADE: A MECHANISM FOR THE WORLDWIDE DISPERSAL OF CONTAINER BREEDING MOSQUITOES

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ABSTRACT. Modern transportation methods have facilitated an extensive trade in used tires at the national and international level. The history and reasons for this trade are described. Comprehensive data on United States imports and United States, Japanese, and Korean exports of used tires for the period 1978–85 reveal an unprecedented potential for the worldwide dispersal of important vector mosquitoes such as *Aedes albopictus* and *Ae. aegypti*. Other articles of commerce with similar potential may await recognition.

INTRODUCTION

The discovery of an established population of *Aedes albopictus* (Skuse), in Houston, Texas (Sprenger and Wuithiranyagool 1986) refocused attention on the importance of used tires as a breeding site for mosquitoes. During studies of this species at a roadside tire dump in Houston, we noticed that an apparently worthless tire was being removed from the site. On inquiry we learned that scavenged tires are sold by at least five local companies to buyers in several southern states and in Mexico, Belize and Guatemala. These companies also buy container loads of used tires from dealers in other parts of the United States and from India, Israel, Japan, Korea, the United Kingdom and West Germany. Many similar companies operate throughout the country.

Although most medical entomologists were unaware of this trade, the United States Department of Agriculture, the Department of Commerce, and the Customs Service confirmed that used tires have been a significant national and international commodity for nearly two decades. Moreover, in the 1960s, during the *Aedes aegypti* Eradication Campaign of the Pan American Health Organization, Haverfield and Hoffman (1966) demonstrated that used tire shipments were important in the dispersal of *Ae. aegypti* (L.) in Texas, and suggested that the mechanism might also be significant at the interstate and international level.

Aedes albopictus is a nonmigratory species with a flight range of less than 1 km (Bonnet and Worchester 1946, Gubler 1971). The apparent rapidity of its spread to so many locations in the United States [Centers for Disease Control (CDC) 1986a, 1986b] is therefore remarkable, and implies an efficient man-made dispersal mechanism. The used tire trade offers precisely such a mechanism. In this paper we describe the trade and discuss its potential impact on medical entomology.

HISTORY OF THE USED TIRE TRADE

The importation of mosquito larvae in tires was first reported in the mid-1940s, when large quantities of war materials ("retrograde cargoes") were returned to the United States from combat zones. The United States Public Health Service (USPHS) found that shiploads of used tires arriving from Asian ports after 5 to 7 weeks of voyage were heavily infested with up to 7 species of mosquitoes, including *Ae. albopictus* (Pratt et al. 1946). Strict measures were enforced to eliminate these insects before the cargoes were discharged. In a review of this and other records of the importation of mosquitoes, Hughes and Porter (1956) concluded that used tires constitute a "... more formidable enemy to mosquito control programs than did the old sailing vessels with their open water supplies".

During the period 1966–75, numerous retrograde cargoes of used tires were transported by air and sea from southeast Asia to the United States by the U. S. government. All shipments were routinely treated with mosquito larvicides during loading, and inspected in quarantine on arrival in the United States. In addition, large quantities of used tires from automobiles, trucks, aircraft, and earthmoving equipment were sold as military surplus in the Republic of Vietnam. However, the civilian buyers who shipped these tires to the United States were not required to treat them with larvicides. Among several partial shiploads of such tires that were inspected by the USPHS, a small infestation of *Ae. albopictus* was found on one occasion (Eads 1972).

According to trade sources, dealers in the United States began importing used tires from civilian dealers in other countries at about the same time that surplus military tires were being sold in Vietnam. Buyers began importing from Japan in 1968, but Europe and Canada were the

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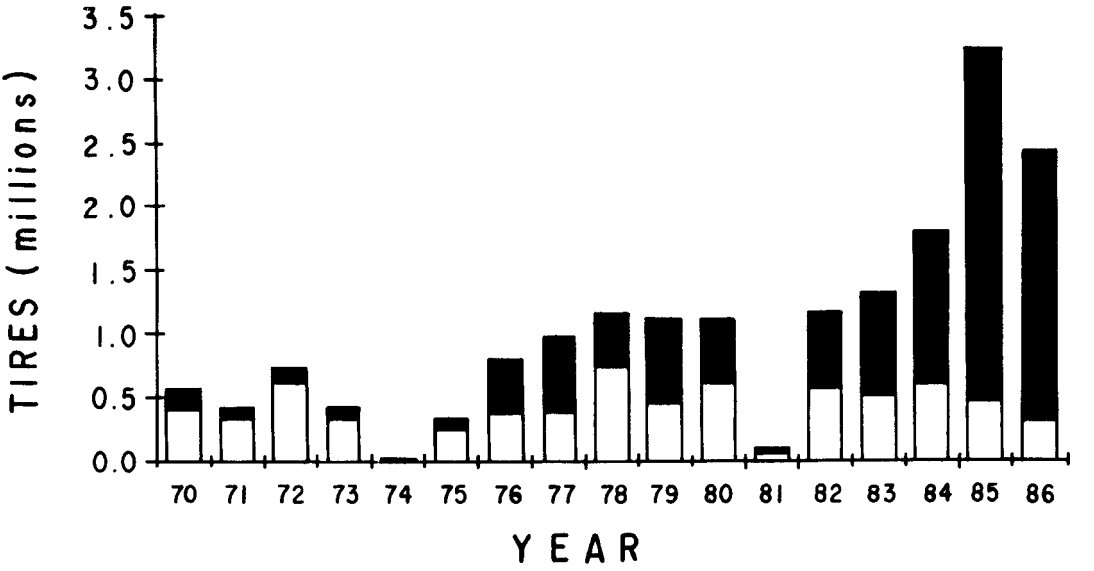

Fig. 1. Imports of used tires by the United States, 1970–85. Imports from areas where *Aedes albopictus* is indigenous are shaded. Source: U.S. Department of Commerce,[3] (Adapted from Hawley et al. (1987) with permission from *Science*).

major sources until the mid 1970s. In 1970, the first year for which official trade data are available[3] 568,862 used tires were imported, of which 157,008 (27.6%) were from countries where *Ae. albopictus* is indigenous (Taiwan 61, 600, Japan 60,794, India 34,614). Used tire imports from such countries have increased greatly, particularly since the end of 1981, while imports from other areas, mainly Europe and Canada, have remained fairly constant (Fig. 1).

UTILIZATION OF USED TIRES

The majority of used tires are traded for reuse on vehicles. Differences in legislation and law enforcement concerning permissible tire wear, the use of recaps, and other criteria mean that tires which are not usable in one country are often acceptable in others. Enforcement is particularly strict in the European Economic Community and in Japan. Tires imported from these countries are often sold directly to consumers, without modification.

Not all used tires imported by the United States are for domestic use. Large quantities are exported to other countries, with or without recapping. In addition, tires for airplanes, earth moving equipment, military equipment and other special applications are often received for repair or recapping and then returned to their owners.

Other options for utilization include:

1. Whole tires
   a. Recapping
   b. Incineration as fuel
   c. Artificial reefs
   d. Crash barriers, boat fenders
   e. Soil erosion control
   f. Temporary tracks for crawler vehicles
   g. Frost prevention
2. Chopped/shredded tires
   a. Landfill
   b. Incineration as fuel
   c. Sludge composting
3. Ground tires
   a. Rubber products, such as porous hosepipe for irrigation
   b. Rubberized asphalt
4. Cut/stamped/dyed tires
   a. Miscellaneous articles, e.g., sandals, floormats and gaskets
5. Reclamation of materials
   a. Carbon black
   b. Natural rubber

The prevalence of these uses varies between countries and with time, depending on economic factors such as fuel costs and commodity prices. National data on utilization are not available for the United States, but information for Japan is summarized in Fig. 2. In the United States,

[3] United States Department of Commerce, Bureau of the Census. Imports for consumption, TSUSA category 7725155. Monthly data on microfiche. Also U.S. Imports for Consumption and General Imports, TSUSA commodity by country of origin, category 7725155 (pre 1978: category 7257072). Annual data in printed form, series FT246 and IM146.

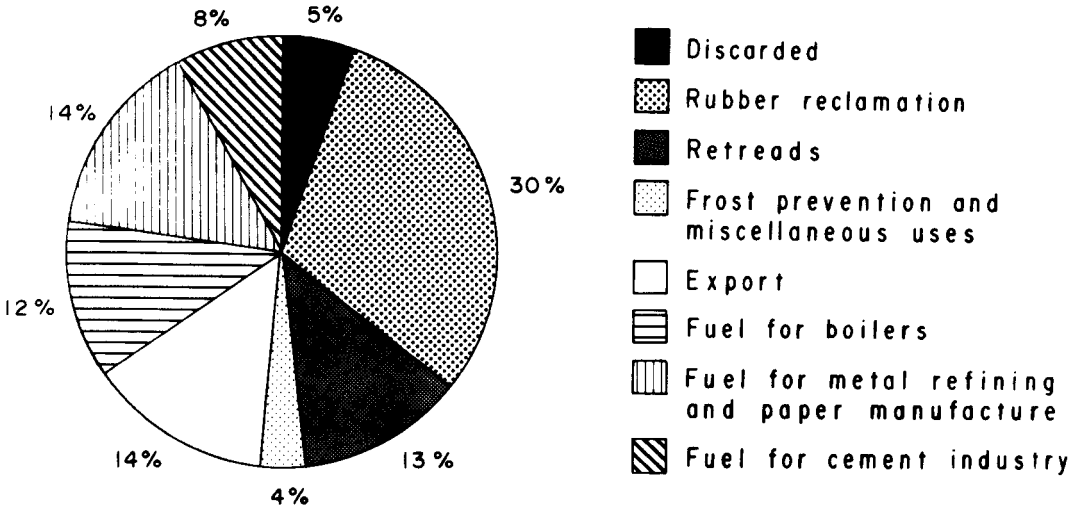

Fig. 2. Utilization of used tires in Japan. Source: Japanese Automobile Tire Manufacturer's Association, Inc.

differences in supply and demand at the local level result in a large volume of tire movements within the country. Large dealers are usually located in highly populated, industrial areas and distribute to smaller towns and rural areas. Specialists in certain kinds of tires, such as balloon tires for swamp vehicles or giant tires for quarry equipment, garner their tires from all over the country and accumulate stocks to cater to sudden demand. Tires are frequently stored outdoors, and marketable stock is often kept adjacent to quasipermanent piles of unusable tires. The latter clearly serve as reservoirs for mosquitoes, facilitating rapid infestation of new stock as it arrives.

IMPORT/EXPORT DATA

United States. In the period 1978–85, the United States imported[3] 11.6 million used tires from 58 countries (Table 1), 7.6 million of which were from 13 countries where *Ae. albopictus* is indigenous. In the same period, the United States exported[4] over 6.3 million used tires to more than 60 countries (Table 2). Imports under "Free Trade Zone" regulations, for re-export, are not included in these data, but are also considerable. For example, a dealer interviewed in Houston had just arranged a shipment of 300,000 used truck tires from Bordeaux, France to Shanghai, China, via New York and Houston. Such shipments often involve sorting, grading and recapping at locations in the United States before export.

According to the U. S. Department of Commerce, Taiwan is the largest exporter of used tires to the United States but informants in the trade deny that this is true. Some sources have suggested that shipments from Taiwan and Hong Kong are augmented by transhipments from other countries in order to exploit favorable trade tariffs[5].

Japan. Japanese imports of used tires are relatively small[6] but in the period 1978–85, Japan exported 15.6 million used tires[7] to more than 80 countries (Table 3). Japan had a larger share (2.4 million) of the total used tire market in the Caribbean and Central and South America than the United States (1.7 million). Many countries bought from both countries, but one of the two was usually dominant. For example, Japan had 91.8% of the market in the Dominican Republic and 99.6% in Haiti, whereas the United States had 99.6% in Mexico and 100% in Venezuela.

Other countries. The Republic of Korea is the only other Asian country for which we have been

[4] United States Department of Commerce, Bureau of the Census. U. S. Exports, Schedule E, commodity by country, TSUSA categories 7725160, 6257027, 6257070, 6257072 and 6257074, depending on year. Annual data in printed form, series FT446 and EM546 (through 1979), series FT410 (1980 and after).

[5] At the time of printing, the U. S. Department of Commerce have informed us that there are serious errors in their published data on imports of used tires from Taiwan for 1985 and 1986. Apparently this is the result of an error in the classification of data supplied by the U. S. Customs authorities. We have no information on the accuracy of data for Taiwan in previous years.

[6] United Nations Statistical Office, New York Branch, "COMTRADE" database, category No. 625.99, computer database SITC Rev. 2.

[7] Japanese Tariff Association. Japanese exports and imports. Exports of commodity by country. Category 40-11-510. Monthly data in printed form.

Table 1. Imports of used tires by the United States, 1978–85. (Source: U. S. Department of Commerce, Bureau of the Census[3]).

Country	Total	Country	Total
AMERICAS		ASIA	
Brazil	5,736	China	14
Canada	1,644,831	Hong Kong	296,792
Colombia	15	India	23,304
Dominican Republic	447	Indonesia	1,231
Jamaica	488	Israel	66,058
Mexico	347,646	Japan	3,437,811
Netherlands Antilles	637	Malaysia	728
Peru	16,897	Oman	523
Suriname	9,971	Pakistan	53
Trinidad	110,006	Philippines	1,530
Uruguay	204	Republic of Korea	141,449
Venezuela	408	Saudi Arabia	264
		Singapore	834
TOTAL	2,137,286	Sri Lanka	792
		Taiwan	3,693,791
EUROPE		Thailand	1
Austria	945	Turkey	6
Belgium	81,708		
Bulgaria	123	TOTAL	7,665,181
Czechoslovakia	4,540		
Denmark	1,375	AFRICA	
Federal Republic of Germany	244,731	Niger	304
Finland	1,312	South Africa	16
France	91,311		
German Democratic Republic	5,143	TOTAL	320
Greece	381		
Hungary	11,606	PACIFIC	
Ireland	13,984	Australia	2
Italy	41,010	French Polynesia	12
Netherlands	223,404	New Zealand	2,973
Norway	341		
Poland	8,192	TOTAL	2,987
Portugal	8,081		
Romania	578	WORLD TOTAL	11,590,921
Spain	7,481		
Sweden	40,266		
Switzerland	2,430		
United Kingdom	908,542		
U.S.S.R.	457		
Yugoslavia	87,206		
TOTAL	1,785,147		

able to obtain export information (Table 4). Korean exports of used tires are reported to the United Nations under category SITC 625.99, which is mainly composed of used tires but includes some other items such as new tires for artillery weapons and baby carriages. In the period 1978–84, Korea reported 16.6 thousand metric tons of exports under this category (tires for road vehicles are 100–300 per metric ton).

SIGNIFICANCE OF MODERN TRANSPORTATION METHODS

In the past two decades, a revolution in cargo handling methods has had more effect on marine transportation than any event since the transition from sail to steam. Containerization, fast container vessels, computerization, and satellite communications have greatly reduced the time it takes to load, ship, and deliver cargoes. Escalating trade volume, short transit times, and favorable environmental conditions inside containers have also greatly increased the number of insect-infested cargos intercepted at ports in the United States (Fig. 3).

Reiter and Darsie (1984) pointed out that these changes constitute a quantum leap in the potential mobility of arthropod vectors. Their study was prompted by the appearance of a single specimen of *Ae. albopictus* in Memphis,

Table 2. Exports of used tires by the United States, 1978–85. (Source: U.S. Department of Commerce, Bureau of the Census[4]).

Country	Total	Country	Total
AMERICAS		PACIFIC	
Argentina	6,123	Australia	36,739
Bahamas	2,416	New Zealand	3,099
Bolivia	548	Papua New Guinea	1,182
Brazil	8,256		
Canada	3,520,457	TOTAL	41,020
Chile	4,857		
Colombia	14,989	ASIA	
Costa Rica	7,970	Hong Kong	18,000
Dominican Republic	148,294	Indonesia	356
Ecuador	9,933	Iran	868
El Salvador	3,335	Iraq	100
Guatemala	11,338	Israel	19,569
Guyana	3,530	Japan	26,914
Haiti	806	Jordan	4,805
Honduras	45,499	Kuwait	11,655
Jamaica	16,357	Lebanon	909
Leeward Islands	4,518	Qatar	1,590
Mexico	839,828	Republic of Korea	400
Netherlands Antilles	33,200	Saudi Arabia	264,669
Nicaragua	46,007	Singapore	518
Panama	33,559	Thailand	555
Peru	10,163	United Arab Emirates	2,556
Trinidad and Tobago	45,672		
Venezuela	383,520	TOTAL	353,464
		AFRICA	
TOTAL	5,201,175	Egypt	3,385
		Libya	625
EUROPE		Morocco	340
Austria	556	Nigeria	8,408
Belgium	13,120	South Africa	26,219
Denmark	42,467	Senegal	603
Federal Republic of Germany	93,886		
France	63,811	TOTAL	39,580
Greece	4,060		
Iceland	12,007	Not Specified	216,823
Italy	82,031		
Netherlands	20,526		
Norway	1,015	WORLD TOTAL	6,343,856
Spain	905		
Sweden	18,538		
Switzerland	3,903		
United Kingdom	134,969		
TOTAL	491,794		

Tennessee. They were unaware of the existence of the worldwide trade in used tires and speculated that this mosquito had travelled as an adult in a container delivered to the area. They also failed to realize that containerization has facilitated commerce in many items that were simply impractical to transport by previous methods. Used tires are a good example: because they are an awkward, bulky item, they were once very costly to handle, particularly at the dockside. By contrast, they now move directly from seller to buyer in containers, and importers range from large, national companies importing thousands of container loads per year to small businesses that make occasional orders for a single container.

PORT INSPECTION

In the United States, imported goods are not inspected for insects of medical importance, although selected cargoes are inspected for agricultural and veterinary pests. Tires are routinely checked by the U. S. Customs Service, and must

Table 3. Japanese exports of used tires, 1978–86. (Source: Japanese Tariff Association[7]).

Country	Total	Country	Total
AMERICAS		ASIA	
Belize	1,966	Afghanistan	19,109
Brazil	3,267	Bahrain	244
Canada	292,680	Bangladesh	3,533
Cayman Islands	2,615	China	1,064,345
Chile	6,462	Hong Kong	3,889,034
Cuba	1,099	Indonesia	738
Dominican Republic	1,660,033	Iran	136
Dominica	41,292	Iraq	6,662
El Salvador	10,203	Jordan	12,724
Guatemala	3,880	Lebanon	53
Haiti	192,278	Macao	728
Honduras	10,191	Malaysia	13,500
Jamaica	2,610	North Korea	5,950
Mexico	3,336	Oman	400
Netherlands Antilles	282	Pakistan	2,229,664
Panama	88,735	Philippines	886,824
Paraguay	10	Qatar	210
Puerto Rico	12,526	Republic of Korea	1,320
St. Lucia	490	Saudi Arabia	122
St. Pierre/Miquelon	296	Singapore	70,335
Suriname	3,538	Sri Lanka	226,659
Trinidad and Tobago	31,782	Taiwan	4,511
United States	2,911,606	Thailand	4,158
U. S. Virgin Islands	710	United Arab Republics	2,309
		Vietnam	76,109
TOTAL	5,281,887	Yemen	50
EUROPE			
Belgium	2,234	TOTAL	8,519,427
Cyprus	3,495		
Federal Republic of Germany	25,142	AFRICA	
Finland	609	Algeria	40
France	35	Botswana	1,104
Iceland	1,759	Cameroon	1,060
Italy	20	Kenya	1,900
Netherlands	10,672	Mauritius	1,882
Poland	1,070	Morocco	510
Portugal	585	Nigeria	42
United Kingdom	23,385	Senegal	792
		Somalia	10
TOTAL	69,006	South Africa	1,065,211
		Swaziland	491
PACIFIC		Tanzania	912
Australia	640,724	Togo	3,890
Fiji	10,310	Zambia	12
Guam	69		
Mariana/Caroline Islands	8,933	TOTAL	1,077,892
New Zealand	1,000		
Papua New Guinea	300	WORLD TOTAL	15,610,913
Samoa	100		
Tonga	965		
Western Samoa	300		
TOTAL	662,701		

be steam cleaned under the supervision of the U. S. Department of Agriculture if they are contaminated with earth, to avoid the importation of animal viruses and plant nematodes. However, there is no requirement to search for water or mosquitoes, nor even to record if they happen to be present. The time and labor required to unload, inspect, and repack containers

Table 4. Exports of used tires (metric tons) by South Korea to a selection of countries, 1978–84. (Source: United Nations Statistical Office[6]).

Country	Total	Country	Total
AMERICAS		AFRICA	
Antigua/Barbuda	6	Angola	1,507
Barbados	43	Benin	32
Bolivia	1,160	Burundi	118
Chile	2,071	Cameroon	56
Colombia	1,944	Djibouti	68
Costa Rica	552	Egypt	3,837
Dominican Republic	1,101	Ethiopia	943
Dominica	1,323	Ghana	3,449
Ecuador	1,777	Ivory Coast	488
El Salvador	203	Kenya	1,139
Guatemala	144	Liberia	527
Guyana	14	Libya	2,123
Haiti	257	Malawi	392
Honduras	3,325	Mozambique	82
Mexico	5,178	Nigeria	2,377
Netherlands Antilles	248	Sierra Leone	709
Nicaragua	657	Somalia	979
Panama	3,103	South Africa	74
Paraguay	107	Sudan	1,152
Peru	180	Tanzania	333
Suriname	490	Togo	15
Trinidad & Tobago	215	Tunisia	1
United States	167,855	Uganda	36
Uruguay	373		
Venezuela	9,678	TOTAL	20,437
TOTAL	202,004	PACIFIC	
		Australia	16,419
MEDITERRANEAN		New Zealand	174
France	169		
Greece	503	TOTAL	16,593
Italy	1,226		
Portugal	44	WORLD TOTAL	253,203
Spain	139		
Turkey	12,088		
TOTAL	14,169		

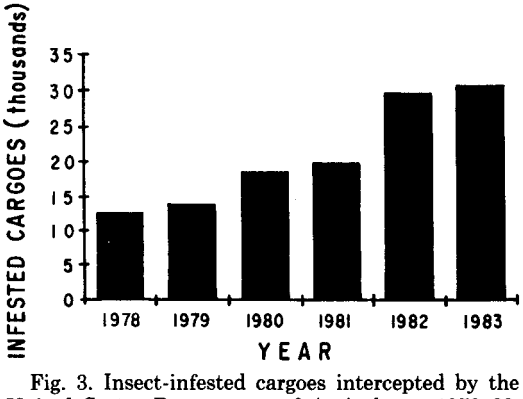

Fig. 3. Insect-infested cargoes intercepted by the United States Department of Agriculture, 1978–83. Source: USDA APHIS PPQ List of intercepted plant pests. Printed annually or biannually.

of used tires preclude routine cleaning of these cargoes by the Department of Agriculture.

CONCLUSION

At the time of writing, infestations of *Ae. albopictus* have been found in twelve states in the United States and four in Brazil (CDC 1986a, 1986b). Nearly all infestations have been in tires, although this probably reflects bias in search procedure. In late 1986, larvae of *Ae. albopictus* and four other mosquito species were found in two container loads of used tires inspected in the Port of Seattle, Washington, less than three weeks after they were shipped from Asia (CDC 1986b and unpublished information).

Larvae of *Ae. albopictus* have also been found in newly imported used tires in Barbados, West Indies (PAHO/WHO, unpublished information). There is little reason to doubt, therefore, that the used tire trade has been a major factor in the establishment and dispersal of *Ae. albopictus* in the western hemisphere.

Several points emerge from this conclusion:

(1) There is no reason to suppose that *Ae. albopictus* is the only container breeding mosquito to have become established after introduction in used tires. The species is conspicuous and easy to identify, yet its widespread distribution in the United States was only recognized after the Houston infestation was made public. Other, less readily identifiable species may also have become established and simply await detection.

(2) Used tires are a well-recognized mosquito breeding site, but other items of modern commerce can serve the same purpose. Examples include the large quantities of iron buckets, bowls and other water-holding containers which are exported from Asia to many countries in Africa and Asia, used construction machinery which is sold to buyers around the world, and cut orchids which are packed in wet wood shavings and shipped from southeast Asia to many countries in Europe and the Americas.

(3) Because the container trade is an international phenomenon, all countries face the risk of importation of vector species. The reintroduction of *Ae. aegypti* into Europe or *Anopheles gambiae* Giles into South America are examples of introductions which could have serious public health consequences.

We believe that these circumstances merit urgent discussion at the international level.

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REFERENCES CITED

Bonnet, D. D. and D. J. Worchester. 1946. The dispersal of *Aedes albopictus* in the territory of Hawaii. Am. J. Trop. Med. Hyg. 26:465–476.

Centers for Disease Control. 1986a. *Aedes albopictus* infestation—United States, Brazil. Morbidity and Mortality Weekly Report 35:493–495.

Centers for Disease Control. 1986b. Update: *Aedes albopictus* infestation—United States. Morbidity and Mortality Weekly Report 35:649–651.

Eads, R. B. 1972. Recovery of *Aedes albopictus* from used tires shipped to United States ports. Mosq. News 32:113–114.

Gubler, D. J. 1971. Ecology of *Aedes albopictus.* The Johns Hopkins University, CMRT, Annual Report: 75–80.

Haverfield, L. E. and B. I. Hoffman. 1966. Used tires as a means of dispersal of *Aedes aegypti* in Texas. Mosq. News 26:433–435.

Hawley, W. A., P. Reiter, R. S. Copeland, C. P. Pumpuni and G. B. Craig, Jr. 1987. *Aedes albopictus* in North America: probable introduction in used tires from northern Asia. Science 236:1114–1116.

Hughes, J. H. and J. E. Porter. 1956. Dispersal of mosquitoes through transportation, with particular reference to immature stages. Mosq. News 16:106–111.

Pratt, J. J., Jr., R. H. Heterick, J. B. Harrison and L. Haber. 1946. Tires as a factor in the transportation of mosquitoes by ships. Mil. Surgeon 99:785–788.

Reiter, P. and R. F. Darsie, Jr. 1984. *Aedes albopictus* in Memphis, Tennessee (USA): an achievement of modern transportation? Mosq. News 44:396–399.

Sprenger, D. and T. Wuithiranyagool. 1986. The discovery and distribution of *Aedes albopictus* in Harris County, Texas. J. Am. Mosq. Control Assoc. 2:217–218.